HEAVY RAINFALL IN MISSISSIPPI AND ALABAMA ON MARCH 27 TO 29, 1951

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INTRODUCTION

The widespread, heavy rain that fell over much of the States adjacent to the Gulf of Mexico on March 27 and 28, was of unusual interest not only because of the flooding conditions that it helped initiate but also because the causes were not obvious from a cursory examination of the usual synoptic charts. The degree of convergence over the area could not be readily accounted for in terms of strong cyclonic flow, squall lines, frontal action, etc. Instability, augmented by cold air advection aloft or upslope motion, apparently was not an important factor since none of the available temperature soundings in the area yielded any supporting evidence of such activity. Although many factors appeared to play roles in the production of strong convergence and therefore abnormal precipitation, none seemed to be a primary influence.

THE PRECIPITATION PATTERN

Above-normal 24-hour precipation amounts were first reported on the morning of March 26 in southern Texas. The area covered on this day was small (approximately 30,000 square miles) in comparison to the size it subsequently reached and the maximum amount recorded at any point was only 1.7 in. By March 27, the area of abnormal precipitation amounts had doubled, covering eastern Texas, western Louisiana, and part of Arkansas. On March 28, the band of heavy rainfall had spread into Mississippi and Alabama and parts of surrounding States. The zone of maximum intensity lay through the center of Mississippi (fig. 1). On the following day (fig. 2) the maximum shifted eastward into central and northern Alabama. After March 29, the heavy precipitation area shrunk in size and decreased greatly in intensity but continued its slow eastward displacement.

The greatest intensity of precipitation occurred in Mississippi and Alabama resulting in widespread flooding in both States. In the former the maximum intensity was recorded at most locations near 0500 GMT of March 28, while in the latter it occurred approximately 24 hours later. A concept of the widespread nature of the heavy precipitation that occurred on these two days may be had from the number of counties in each State in which 24-hour amounts were exceedingly high. Of Mississippi's 81 counties, 22 contained stations reporting amounts at 1230 GMT on March 28 in excess of 3 in. Of those 22, at least

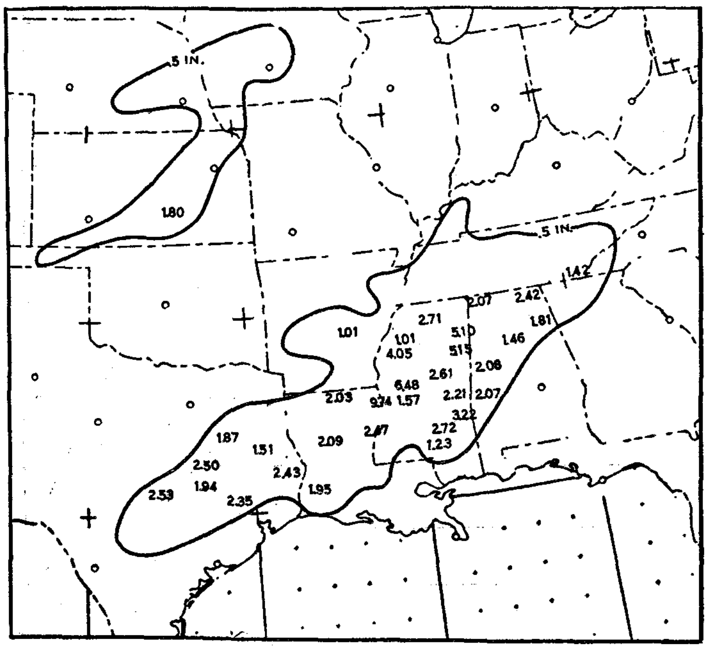

FIGURE 1.—24-hour rainfall reported at 1230 GMT on March 28, 1951. Solid lines delineate areas of 0.50 in. or more. Numbers indicate amounts in hundredths of an inch for "first-order" stations reporting 1.00 in. or more.

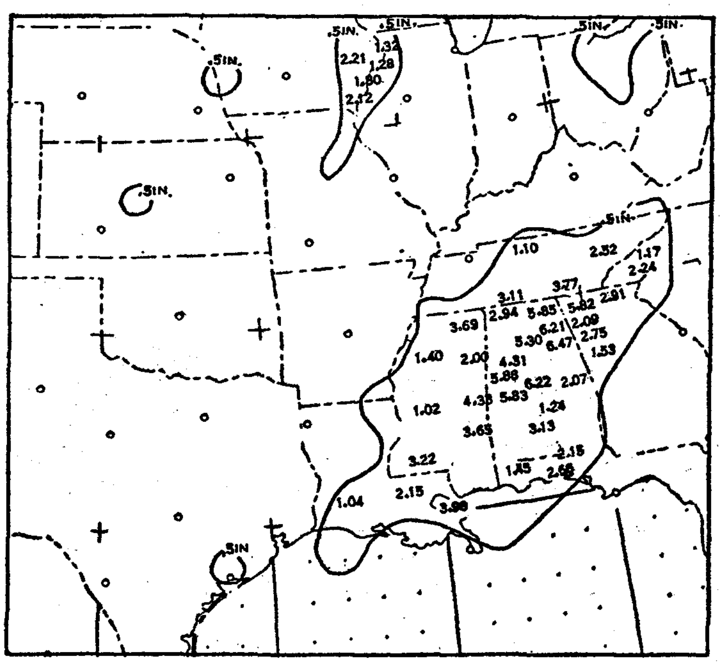

FIGURE 2.—24-hour rainfall reported at 1230 GMT on March 29, 1951.

11 contained reports of amounts greater than 5 in. In Alabama at 1230 GMT on March 29, there were reports in at least 27 of the State's 67 counties of amounts greater than 3 in. with 20 counties containing reports of over 5 in. One first-order station, Vicksburg, Miss., set a new record of 9.74 in. in 24 hours. The previous record, set on July 13, 1907, was 7.99 in.[1].

MOISTURE SUPPLY

Considering the exceedingly heavy rainfall that occurred over a wide area, it is to be anticipated that there was present in the region ample moisture replenishment in addition to a mechanism for releasing the precipitation. That there was an abundant supply of moisture being advected into the region from the Gulf of Mexico is evident from the flow patterns that existed at most levels throughout the atmosphere (figs. 3, 4, and 8). The evolvement of the flow pattern of 0300 GMT, March 28, with its strong advection of moisture over the Gulf States, was very rapid. The large increase in humidity below 630 mb. in one day, illustrated by the 0300 GMT soundings of Little Rock, Ark., of March 27 and 28 (fig. 5), is evidence of the rapidity with which the strong southerly flow developed. Until 0300 GMT, March 26, most of the southern States were dominated by northwest winds at most levels in the atmosphere, but within 24 hours, the entire region was covered by southerly winds which increased rapidly in speed immediately after the shift in direction. This sudden change was brought about by the approach of an intensifying trough from the west. The trough, which originated with a cold incursion from the Pacific Ocean and intensified only slightly during its passage over the Rockies, strengthened abruptly as it moved into the Plains on March 27.

Some idea of the replenishment rate required to produce rainfall of the magnitude reported over a wide area can be obtained from the simple calculations demonstrated by Showalter [2]. Taking the sounding of 0300 GMT, March 28, at Little Rock, Ark., to be representative of

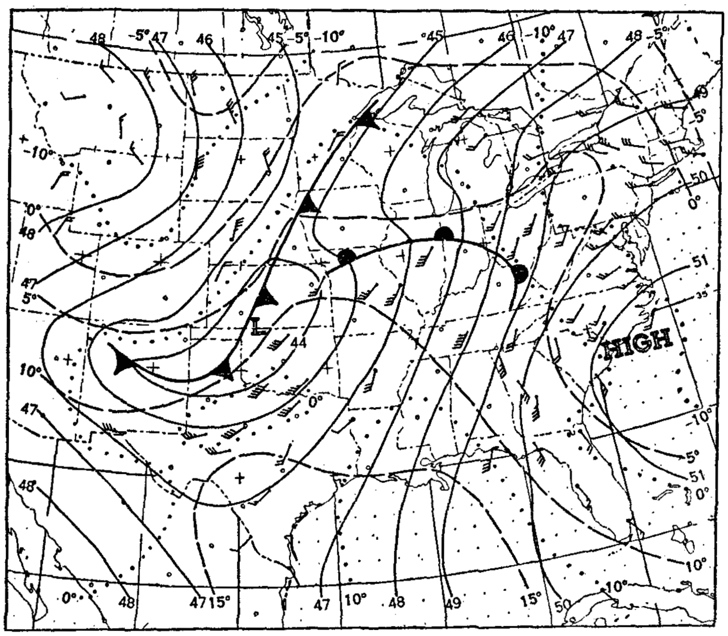

FIGURE 3.—850-mb. chart for 0300 GMT, March 28, 1951. Contours (solid lines) at 100-ft. intervals are labeled in hundreds of geopotential feet. Isotherms (dashed lines) are at intervals of 5° C. Lines of equal dew point (dotted) are at intervals of 10°C. Barbs on wind shafts are for speeds in knots (pennant=50 knots, full barb=10 knots, and half barb=5 knots).

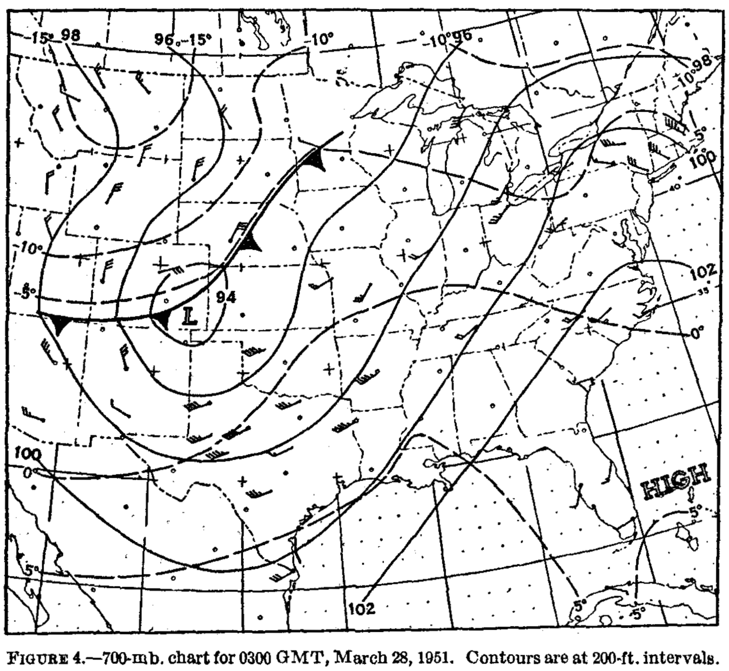

FIGURE 4.—700-mb. chart for 0300 GMT, March 28, 1951. Contours are at 200-ft. intervals.

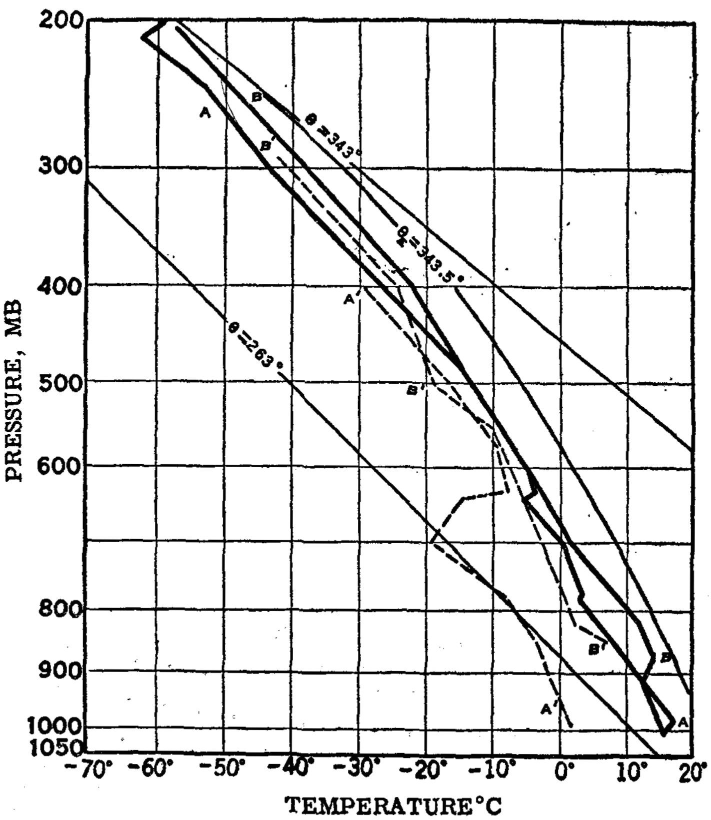

FIGURE 5.—Radiosonde observations at Little Rock, Ark., for 0300 GMT. Curves A and A' denote temperature and dew point, respectively, for March 27, 1951, while curves B and B' are for March 28, 1951.

humidity conditions within the area of abnormal precipitation, and by using Showalter's procedure of summing the moisture content over 50-mb. increments, the amount of precipitable water content in the layer from 1000 mb. to 700 mb. was found to be 0.92 in. If complete convection of this 300-mb.-thick layer were to take place so that all water were removed, in order to deposit 5.5 in. of precipitation in a day over a 50-mile-wide zone, a mean inflow of 12.5 mph would be required (5.5 in.$\times$50 miles/0.92 in.$\times$24 hours). If only one third of the precipitable water (0.30 in.) were removed across this same zone then replenishment would have to be at the mean rate (wind speed) of about 38 mph. If a drier layer such as that between 700 mb. and 400 mb. were the convecting layer then the replenishment rate would necessarily be even greater. An increase in the width of the zone of precipitation would result in the requirement of higher wind velocities. It can be seen from these values that, for heavy precipitation over a wide area and long periods of time, in addition to strong advection of moist air intense convergence would be necessary to bring about sufficient upward motion of the air.

PRECIPITATION MECHANISM

Some concept of the average minimum amount of convergence that occurred in the vicinity of the heavy rainfall may be obtained from Showalter's formula [2], wherein he assumes that the velocity drop across a rainfall basin is representative of the amount of air being forced to convect:

$$I=\frac{W_e(v_1-v_2)}{Y}$$

where (v_1-v_2) is the velocity drop in miles per hour across a basin Y miles wide, I is the intensity of precipitation in inches per hour, and W_e the maximum effective precipitable water (inches) in the air column. W_e was computed from the formula:

$$W_e=0.2\ (p_0-p_1)\ (w_0+w_1-w_z-w_b)$$

where,

p_0=pressure at base of inflow layer (mb.)
p_1=pressure at top of inflow layer (mb.)
w_0=mixing ratio at base of inflow layer (g/g)
w_1=mixing ratio at top of inflow layer (g/g)
w_z=mixing ratio at top of outflow layer (g/g)
w_b=mixing ratio at base of outflow layer (g/g)

In accordance with Showalter's procedure 300 mb. was used for the thickness of the inflow layer. The values of w_0 and w_1 were obtained from the sounding at Little Rock for 0300 GMT, March 28 while w_z and w_b were calculated by assuming that one-third of the moisture of the inflow layer was removed. Thus,

$$W_e=0.2\ (300)\ [0.0110+0.0045-\tfrac{2}{3}\ (0.0110+0.0045)]$$
$$=0.31\ in.$$

Inserting in the first equation the conservative values of 50 miles for Y, 0.2 in./hour (4.8 in./day) for I, and 0.31 in. for W_e derived above, and solving for (v_1-v_2), a velocity drop of approximately 31 mph/50 miles was found.

That such a velocity drop probably existed and may have been far exceeded for short periods of time and over fairly large areas [1] during the occurrence of the heavy rainfall may be inferred from the vertical cross sections of figures 6 and 7 for 0300 GMT, March 27, and 0300 GMT, March 28, respectively. They have been drawn so as to lie approximately parallel to the mean flow direction between 850 mb. and 300 mb. At the same time they skirt the northern edge of the maximum precipitation

[1] Short-duration horizontal convergence over small areas sometimes reaches enormous values. As Byers and Braham [3] point out, values of convergence in the vicinity of micro-lows forming along squall lines could exceed 20/hr.

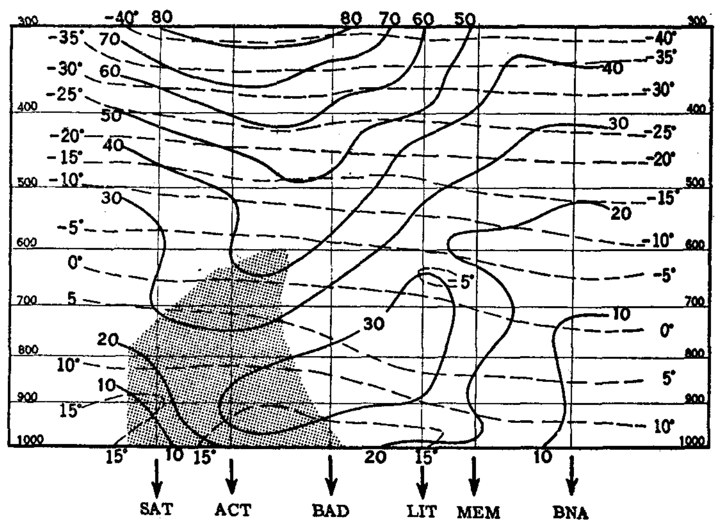

FIGURE 6.—Atmospheric cross section, 0300 GMT, March 27, 1951. Solid lines are isotachs (equal wind speed) in knots, and dashed lines are isotherms in °C. Shaded area indicates relative humidity greater than 80 percent. Station call letters are: SAT=San Antonio, Tex., ACT=Waco, Tex., BAD=Shreveport, La., LIT=Little Rock, Ark., MEM=Memphis, Tenn., BNA=Nashville, Tenn.

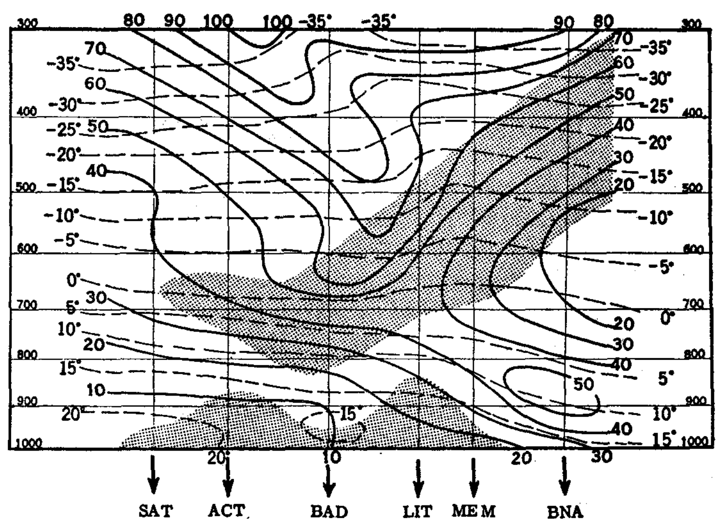

FIGURE 7.—Atmospheric cross section, 0300 GMT, March 28, 1951.

area. The gradient of the lines of equal wind speed (isotachs) give some indication of the existing convergence. It can be seen that on March 28 there existed between Little Rock, Ark., and Nashville, Tenn., a distance of approximately 300 miles, a mean gradient of speed of more than 30 knots in the layer 700-400 mb. A maximum of gradient of 50 knots existed at the 540-mb. level. Contrast the isotach pattern of March 28 with that which existed in the same layer on the previous day. The mean gradient in the layer on March 27 was less than 12 knots. Since the winds aloft observation at Memphis on March 28 was missing it was necessary to draw as even a gradient between Little Rock and Nashville as the available data permitted. It is thus possible that an even stronger gradient than shown existed at some points between the two stations. It is noteworthy that, despite the large increase in speed in the 700–400 mb. layer that occurred upstream from Nashville, only a small change occurred at Nashville. It will also be noted that a definite maximum of wind speed appeared at most levels on March 28 near Shreveport, La. For example, the 60-knot isotach descended from the 420-mb. level on March 27 to about the 660-mb. level on March 28. No significant change in the isothermal structure could be detected.

In order to relate somewhat the convective and advective processes with the zone of wind shear the areas of relative humidity in excess of 80 percent have been shaded on the cross sections. Two interesting changes in moisture distribution during the 24-hour period give rise to certain speculations. (1) Moisture had evidently been carried to high levels principally within the region of strong convergence. (2) The lack of uniformity in degree of saturation east of Little Rock suggests that much of the moisture available at high levels had been advected from farther south rather than convected from the surface directly over the area of heavy rainfall. The strong convergence existent between 700 mb. and 400 mb. plus the fact that the base of the upper deck of clouds over the area under discussion on the early morning of March 28 was generally reported near 10,000 feet lead to the conclusion that much of the activity occurred at levels above the low-level inversion.

INFLUENCE OF THE JET STREAM

The rapid descent of strong, high-level winds as seen in figures 6 and 7 appeared to be associated with a northward migration of an unusually well-developed jet stream. At 300 mb. the jet first appeared on the chart of 0300 GMT, March 27, along the Gulf of Mexico lying between southern Texas and southern Louisiana. That position coincided with the zone of maximum precipitation reported that day. As the amplitude of the wave pattern at 300 mb. increased, through strengthening of both the ridge near 85° W. and the trough near 105° W. (fig. 8), the jet migrated northward to the position over northwestern Louisiana shown at 0300 GMT, March 28.

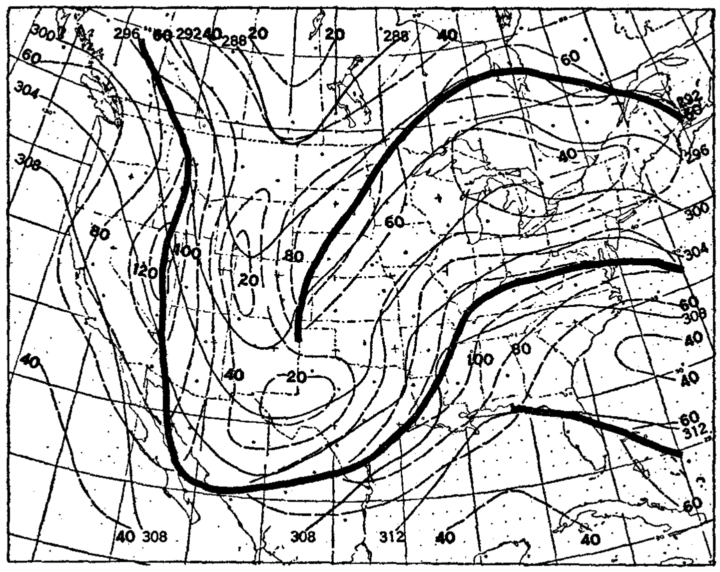

FIGURE 8.—300-mb. chart for 0300 GMT, March 28, 1951. Contours (solid lines) at 400-ft. intervals are labeled in hundreds of geopotential feet. Dashed lines represent isotachs (equal wind speed) and are at intervals of 20 knots. Heavy line represents jet stream.

Although the vertical motion existing in the vicinity of a jet is as yet little understood it was strikingly coincidental that such a well-developed jet [2] moved directly over the region of heavy rainfall near the time of maximum intensity. The model of vertical motion postulated by the University of Chicago [4] calls for sinking, southward motion in the upper troposphere to the south of the jet at 300 mb. and ascending, northward motion below it. Starrett [5] in his investigation of 57 synoptic situations, showed that maxima of precipitation generally occur under the jet at 300 mb. with a standard deviation of maxima of approximately 5° latitude. He also found that where the west wind component of the jet exceeded 50 mps (97 knots) relatively heavier precipitation would occur than where a lesser speed existed. Winds greater than 100 knots were actually reported in this case.

SURFACE AND CONSTANT-PRESSURE CHARTS IN RELATION TO PRECIPITATION

There were several characteristics of the surface and upper-level charts that were indicative of convergence with resulting precipitation. However, none appeared with sufficient intensity nor was coincident with the time of the maximum rainfall. The strong southerly flow of maritime tropical air from the Gulf of Mexico probably produced within itself horizontal convergence as it moved toward northerly latitudes. There was also present in the lower levels (figs. 3 and 4) over the region slight cyclonic curvature of the contours which is conducive to convergence [6]. Another effect to be considered was the presence of a diffuse warm front (figs. 9, 10, and 11) but most of the intense rainfall occurred south of it.

[2] There was an actual reported velocity of 170 knots within the jet at 200 mb.

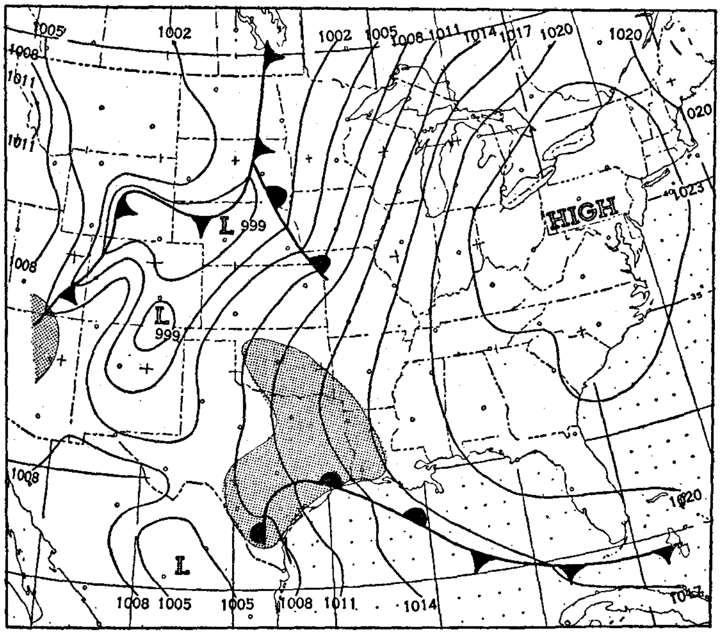

FIGURE 9.—Surface weather chart for 0030 GMT, March 27, 1951. Shading indicates areas of active precipitation.

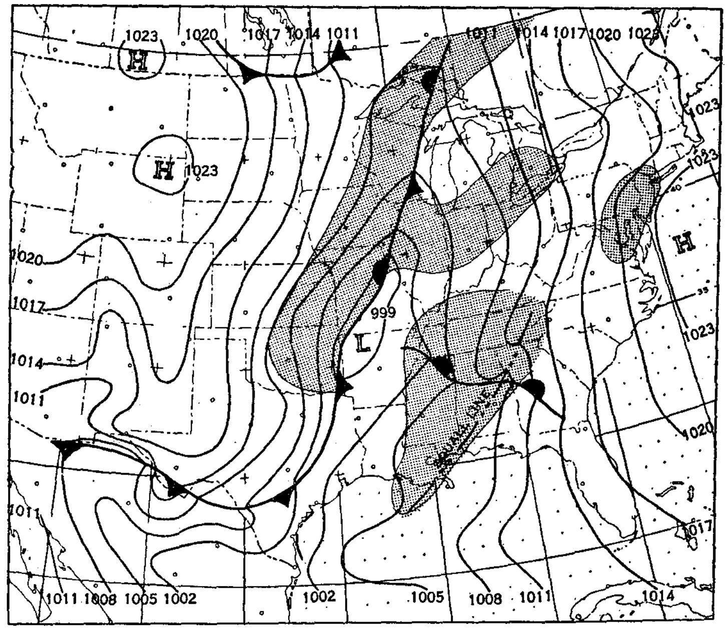

FIGURE 11.—Surface weather chart for 0030 GMT, March 29, 1951.

There was no indication of increasing instability during the 24-hour period prior to the time of maximum precipitation. No advection of cold air was discernible from an examination of either the constant-pressure charts or individual soundings in the area. The soundings at Little Rock (fig. 5) illustrate the small changes that occurred over most of the region.

Since most of the precipitation fell during thunderstorms it might be suspected that squall lines played an important role. In the absence of a dense network of stations providing continuous records of pressure, wind, temperature, etc., it was impossible to perform the highly-refined analysis required to locate squall lines [7]. However, considering the broad east-west extent of the precipitation area, it would appear that only the presence of multiple squall lines could fit the precipitation pattern.

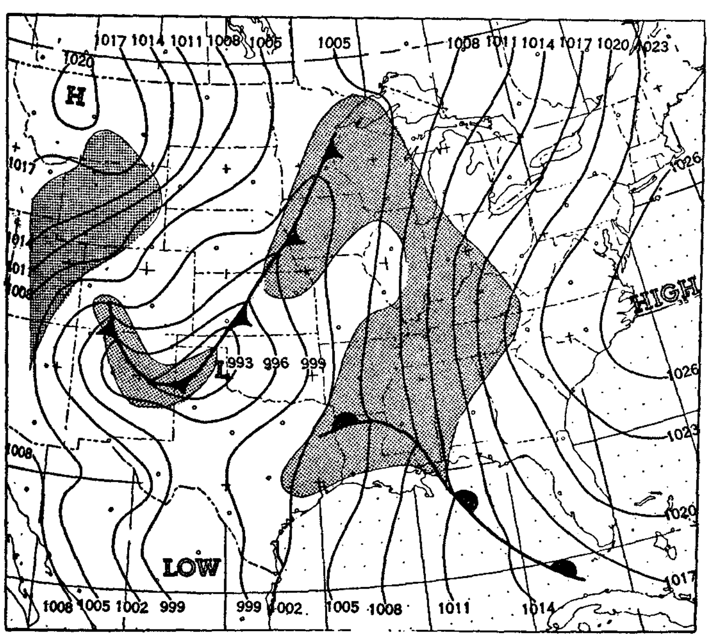

FIGURE 10.—Surface weather chart for 0030 GMT, March 28, 1951.

As for statistical parameters commonly associated with heavy precipitation there were several that were verified in this case. For example, Klein [8] found for 5-day periods that heavy precipitation is typical of the zone ahead of the trough and that the optimum region for its occurrence is about half way from the 700-mb. trough to the first ridge downstream. The 700-mb. chart of figure 4 presents a wave pattern which fulfills those requirements almost exactly. Another favorable factor of the 700-mb. chart is the northeast-southwest orientation of the trough. Strong confluence, considered favorable for heavy precipitation, is indicated by the 850-mb. flow but is not very evident from the 700-mb. chart.

Regardless of the particular synoptic characteristic that may have brought on the heavy precipitation, which in this case is difficult to determine, strong, large-scale convergence must have been present. The mechanism creating these wide areas of convergence remains a problem which is likely to be solved only by a detailed examination of a dense network of stations.

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U. S. GOVERNMENT PRINTING OFFICE: 1951